第十二章
绘图软件介绍

—— PGF/TikZ 绘图

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PGF：Portable Graphics Format

- 开发者：Till Tantau (也是幻灯片宏包 beamer 的作者)
- 主页：http://sourceforge.net/projects/pgf/
- 支持 LaTeX 和 PdfLaTeX 编译
- pgf 可精确绘制复杂的几何图形及各种曲线
- 可以与其它数学(作图)软件配合使用：如 gnuplot, Mathematica
- 丰富的网络资源 (见课程主页上的网络链接) http://www.texample.net/tikz/

pgf 的使用

☞ 使用时只需调用 tikz 宏包 (pgf 的前端)

```
\usepackage{tikz}
```

pgf 的使用

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```
\usepackage{tikz}
```

- 可以根据需要调用 tikz 扩展

```
\usetikzlibrary{arrows,backgrounds,scopes, . . .}
```

pgf 的使用

- 使用时只需调用 tikz 宏包 (pgf 的前端)

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\usepackage{tikz}
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```
\usetikzlibrary{arrows,backgrounds,scopes, . . .}
```

- tikz 绘图也是基于坐标系的，原点在当前位置(左下角)
- 每条绘图命令以分号结束
- 默认长度单位是 1cm
- 使用长度或坐标时，可以带单位，也可以不带单位

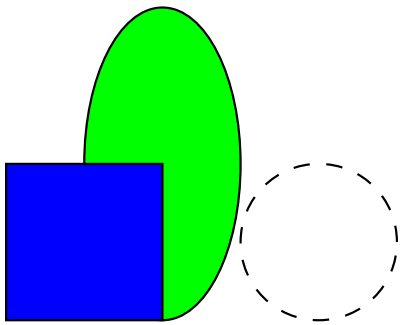
☞ TikZ 绘图的两种使用方式：命令方式和环境方式

➜ 命令方式：\tikz

你 —— 好　　你~\tikz \draw (0pt,0pt) -- (30pt,6pt); 好

你 —— 好　　你~\tikz{\draw (0pt,0pt) -- (30pt,6pt);} 好

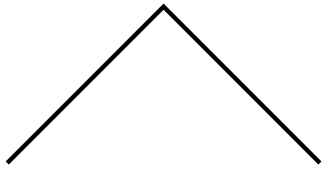
➜ 绘图环境：tikzpicture



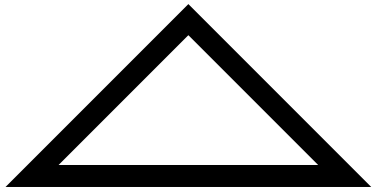
```
\begin{tikzpicture}
  \draw[style=dashed] (2,.5) circle (0.5);
  \draw[fill=green] (1,1) ellipse (.5 and 1);
  \draw[fill=blue] (0,0) rectangle (1,1);
\end{tikzpicture}
```

Path 路径

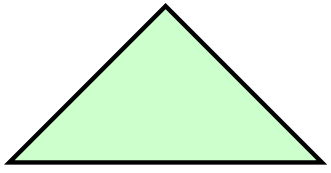
- TikZ 绘图的基本单元是路径
- 路径：The basic building block of all pictures. A path is a series of straight lines and curves that are connected.
- 路径的基本元素：点，连接方式
  - 点：通过坐标或其它方式给出
  - 连接方式：直线，曲线，弧线，...
- 路径可以被画，填充，裁剪，. . .



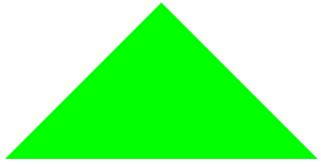
```
\path[draw] (1,1)--(2,2)--(3,1);
```



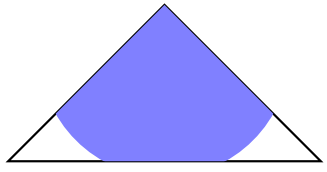
```
\path[draw,line width=4pt]%
     (1,1)--(2,2)--(3,1)--cycle;
```



```
\path[draw, fill=green!20]%
     (1,1)--(2,2)--(3,1)--cycle;
```



```
\path[fill=green]%
     (1,1)--(2,2)--(3,1)--cycle;
```



```
\path[clip, draw]%
     (1,1)--(2,2)--(3,1)--cycle;
\path[fill=blue!50] (2, 1.7) circle (.8);
```

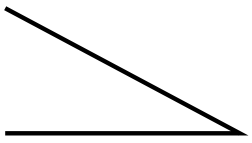
Path 路径

- 通常使用缩写形式

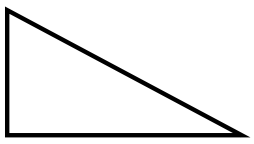
```
\draw = \path[draw]
\fill = \path[fill]
\clip = \path[clip]
\filldraw = \path[fill,draw]
\shade = \path[shade]
  . . .
```

简单作图

- 直线



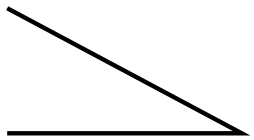
```
\draw (0,0) -- (2,0) -- (0,1);
```



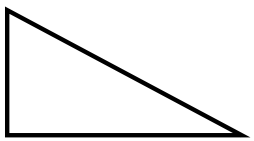
```
\draw (0,0) -- (2,0) -- (0,1) -- cycle;
```

简单作图

- 直线

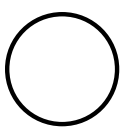


```
\draw (0,0) -- (2,0) -- (0,1);
```

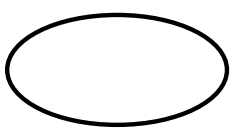


```
\draw (0,0) -- (2,0) -- (0,1) -- cycle;
```

- 园 (圆心，半径)，椭圆 (中心，长半轴，短半轴)



```
\draw (0,0) circle (10pt);
```



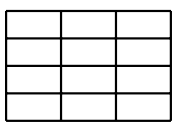
```
\draw (0,0) ellipse (20pt and 10pt);
```

简单作图

☞ 矩形 (对角线上的两个点)

```
\draw (0,0) rectangle (2,1);
```

➜ 步长选项：step，xstep，ystep



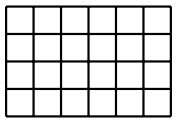
```
\draw[xstep=10pt,ystep=5pt]%
     (0,0) grid (30pt,20pt);
```

简单作图

- 矩形 (对角线上的两个点)

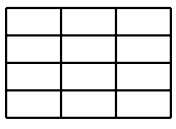
```
\draw (0,0) rectangle (2,1);
```

- 网格



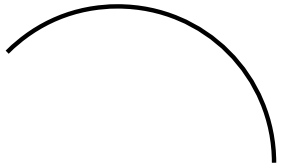
```
\draw[step=5pt] (0,0) grid (30pt,20pt);
```

→ 步长选项：step，xstep，ystep



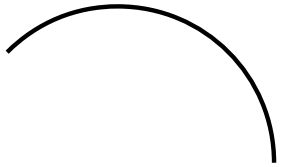
```
\draw[xstep=10pt,ystep=5pt]%
    (0,0) grid (30pt,20pt);
```

☞ 圆弧 (起始点，角度范围，半径)



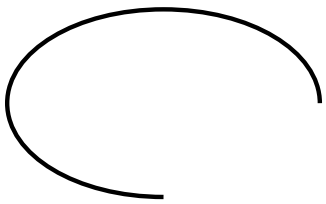
```
\draw (0,0) arc (0:135:1);
```

☞ 圆弧 (起始点，角度范围，半径)



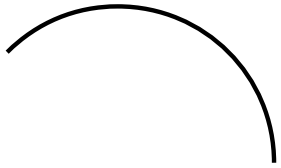
```
\draw (0,0) arc (0:135:1);
```

☞ 椭圆弧 (起始点，角度范围，长半轴，短半轴)



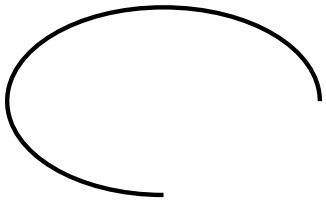
```
\draw (0,0) arc (0:270:1 and 0.6);
```

☞ 圆弧 (起始点，角度范围，半径)



```
\draw (0,0) arc (0:135:1);
```

☞ 椭圆弧 (起始点，角度范围，长半轴，短半轴)



```
\draw (0,0) arc (0:270:1 and 0.6);
```

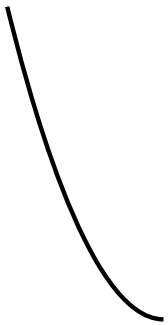
☞ 圆角

```
\draw[rounded corners] (0,0) -- (0,0.5) -- (1,0.5);
```

```
\draw[rounded corners=10pt]%
     (0,0) -- (0,0.5) -- (1,0.5);
```

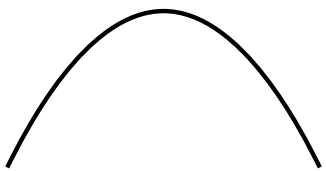
简单作图

☞ 抛物线 (顶点，终点)



```
\draw (0,0) parabola (1,1);
```

➜ 可以使用 bend 选项另外指定顶点



```
\draw (0,0) parabola bend (1,1) (2,0);
```

简单作图

- 一般曲线：三次Bézier 曲线 (两个控制点)

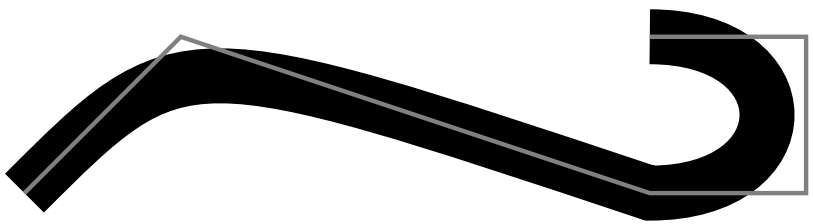
```
\draw (0,0) .. controls (1,1)%
      and (2,1) .. (2,0);
```

简单作图

☞ 一般曲线：三次Bézier 曲线 (两个控制点)

```
\draw (0,0) .. controls (1,1)%
      and (2,1) .. (2,0);
```

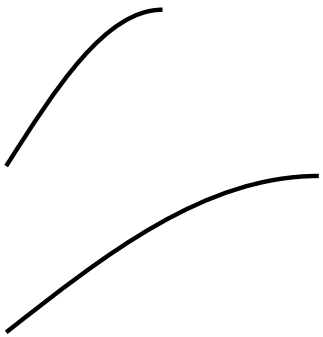
- 若只给一个控制点，则第二个点与第一个点相同



```
\draw[line width=10pt] (0,0) .. controls (1,1) %
     .. (4,0) .. controls (5,0) and (5,1) .. (4,1);
\draw[color=gray] (0,0) -- (1,1) -- (4,0) %
     -- (5,0) -- (5,1) -- (4,1);
```

简单作图

- sin, cos 函数图形：$[0, \pi/2]$



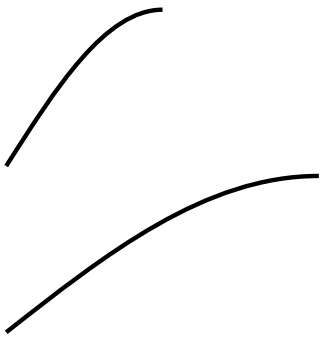
```
\tikz\draw[thick] (0,0) sin (1,1);
```



```
\tikz\draw[thick] (0,0) sin (2,1);
```

简单作图

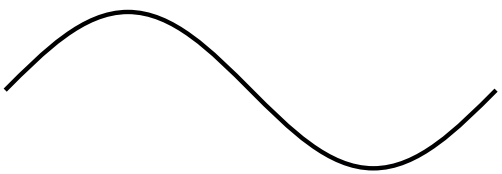
☞ sin, cos 函数图形：$[0, \pi/2]$



```
\tikz\draw[thick] (0,0) sin (1,1);

\tikz\draw[thick] (0,0) sin (2,1);
```

- 只能画$[0, \pi/2]$ 之间的图形



```
\tikz\draw (0,0) sin (1.57,1) cos (3.14,0) %
           sin (4.71,-1) cos (6.28,0);
```

填充

- 填充：\fill, \filldraw

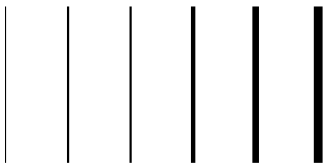
```
\fill[red] (0,0) rectangle (2,1);
```

```
\filldraw[fill=red,draw=blue]%
        (0,0) rectangle (2,1);
```

作图选项

- 线的粗细：line width=长度，也可以使用

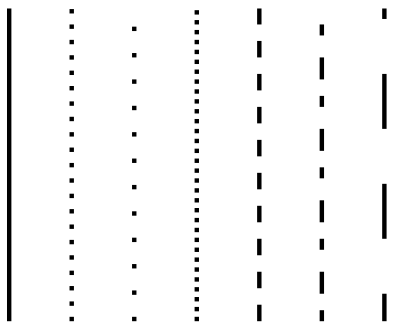
  thin, very thin, ultra thin, thick, very thick, . . .



```
\begin{tikzpicture}
  \draw[very thin]    (0,0) -- (0,1);
  \draw[thin]         (0,0) -- (0,1);
  \draw               (0,0) -- (0,1);
  \draw[thick]        (0,0) -- (0,1);
  \draw[very thick]   (0,0) -- (0,1);
  \draw[ultra thick] (0,0) -- (0,1);
\end{tikzpicture}
```

作图选项

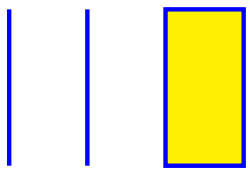
- 线的形状：dash pattern=值，也可以使用
  solid (缺省值)，dashed，densely dashed，loosely dashed，
  dotted，densely dotted，loosely dotted



```
\begin{tikzpicture}[thick]
  \draw (0,0) -- (0,2);
  \draw[dotted] (0,0) -- (0,2);
  \draw[loosely dotted] (0,0) -- (0,2);
  \draw[densely dotted] (0,0) -- (0,2);
  \draw[dashed] (0,0) -- (0,2);
  \draw[dash pattern=on 2pt off 3pt on 4pt %
        off 4pt] (0,0) -- (0,2);
  \draw[dash pattern=on 10pt off 10pt, %
       dash phase=5pt] (0,0) -- (0,2);
\end{tikzpicture}
```

作图选项

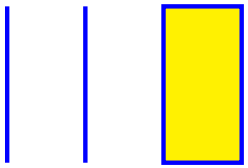
- 颜色：color=颜色，draw=颜色，fill=颜色，. . .



```
\begin{tikzpicture}[thick]
  \draw[color=blue] (0,0) -- (0,1);
  \path[draw=blue] (0.5,0) -- (0.5,1);
  \draw[blue,fill=yellow] (1,0) rectangle (1.5,1);
\end{tikzpicture}
```

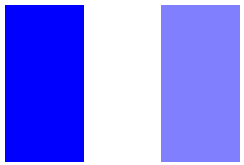
作图选项

- 颜色：color=颜色，draw=颜色，fill=颜色，. . .



```
\begin{tikzpicture}[thick]
  \draw[color=blue] (0,0) -- (0,1);
  \path[draw=blue] (0.5,0) -- (0.5,1);
  \draw[blue,fill=yellow] (1,0) rectangle (1.5,1);
\end{tikzpicture}
```

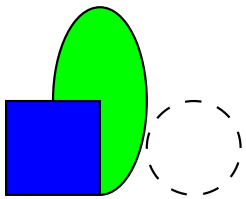
- 透明度：opacity=值



```
\begin{tikzpicture}
  \fill[blue] (0,0) rectangle (0.5,1);
  \fill[blue,opacity=0.5] (1,0) rectangle (1.5,1);
\end{tikzpicture}
```

作图选项

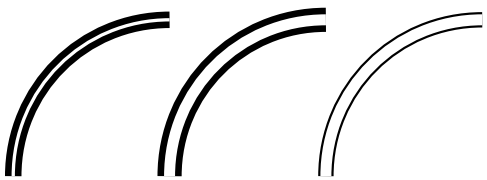
- 缩小或放大图形：scale=倍数



```
\begin{tikzpicture}[scale=0.6]
  \draw[style=dashed] (2,.5) circle (0.5);
  \draw[fill=green] (1,1) ellipse (.5 and 1);
  \draw[fill=blue] (0,0) rectangle (1,1);
\end{tikzpicture}
```

作图选项

- 双线：double
  - 双线之间的距离：distance=距离

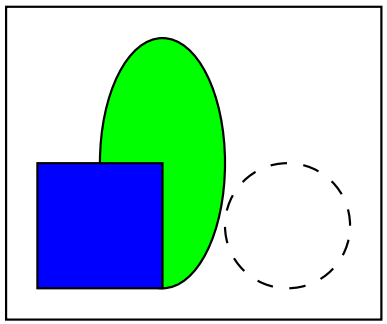


```
\begin{tikzpicture}[very thick]
  \draw[double] (0,0) arc (180:90:1cm);
  \draw[double distance=2pt] %
       (1,0) arc (180:90:1cm);
  \draw[thin, double distance=2pt] %
       (2,0) arc (180:90:1cm);
\end{tikzpicture}
```

  - double distance 之间不能加逗号

☞ 显示绘图区域边界：backgrounds 扩展

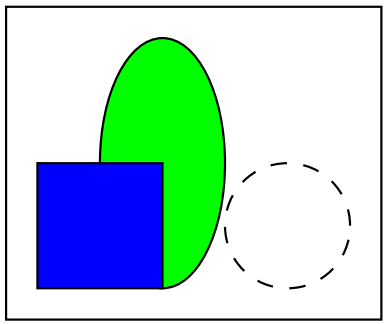
```
\usetikzlibrary{backgrounds}
```



```
\begin{tikzpicture}%
        [scale=0.8, show background rectangle]
  \draw[style=dashed] (2,.5) circle (0.5);
  \draw[fill=green] (1,1) ellipse (.5 and 1);
  \draw[fill=blue] (0,0) rectangle (1,1);
\end{tikzpicture}
```

☞ 显示绘图区域边界：backgrounds 扩展

```
\usetikzlibrary{backgrounds}
```



```
\begin{tikzpicture}%
        [scale=0.8, show background rectangle]
  \draw[style=dashed] (2,.5) circle (0.5);
  \draw[fill=green] (1,1) ellipse (.5 and 1);
  \draw[fill=blue] (0,0) rectangle (1,1);
\end{tikzpicture}
```

☞ 可使用 minipage 环境或 \hspace*, \vspace 将图像放置到指定的地方

阴影

☞ 阴影：\shade, \shadedraw

```
\shade (0,0) rectangle (2,1)
```

➜ 默认是从上到下，从灰到白渐变

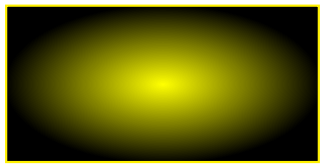
➜ 可使用下面的选项指定颜色的变化方式

left, right, top, bottom, inner, outer, ball

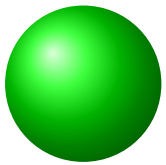
阴影

```
\tikz\shade[top color=yellow,%
      bottom color=black]%
      (0,0) rectangle (2,1);
```

```
\tikz\shade[left color=yellow,%
      right color=black]%
      (0,0) rectangle (2,1);
```



```
\tikz\shadedraw[inner color=yellow,%
      outer color=black,draw=yellow]%
      (0,0) rectangle (2,1);
```



```
\tikz\shade[ball color=green]%
      (0,0) circle (.5cm);
```

坐标

☞ 指定坐标的几种方式：

➜ 使用直角坐标 (x, y)，如：(0,1)， (0.4cm,5pt)

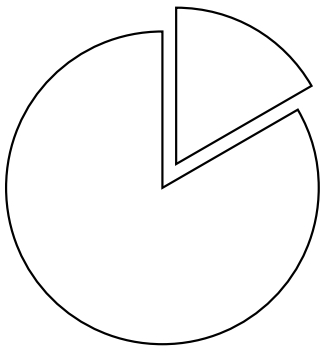
➜ 使用极坐标 $(\theta : r)$，如：(30:1cm)

➜ 使用相对位置：

- 一个加号：+(0,5pt) (从当前点向上移 5pt)
- 两个加号：++(0,5pt) (从当前点向上移 5pt)

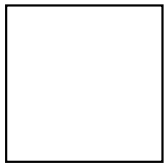
坐标

- ☞ 指定坐标的几种方式：
- ➜ 使用直角坐标 (x, y)，如：(0,1)， (0.4cm,5pt)
- ➜ 使用极坐标 $(\theta : r)$，如：(30:1cm)
- ➜ 使用相对位置：
  - 一个加号：+(0,5pt) (从当前点向上移 5pt)
  - 两个加号：++(0,5pt) (从当前点向上移 5pt)
- ☞ 相对位置的使用

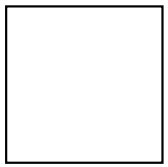


```
\draw (0,0) -- (90:1cm) arc (90:360:1cm) %
      arc (0:30:1cm) -- cycle;
\draw (60:5pt) -- +(30:1cm) arc %
      (30:90:1cm) -- cycle;
```

坐标



```
\draw (0,0) -- ++(1cm,0cm) -- ++(0cm,1cm)
           -- ++(-1cm,0cm) -- cycle;
```

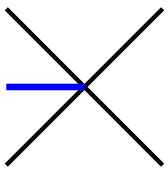


```
\draw (0,0) -- +(1cm,0cm) -- +(1cm,1cm)
           -- +(0cm,1cm) -- cycle;
```

- 一个加号：不更新当前点的位置
- 两个加号：更新当前点的位置

坐标

➜ 使用交点

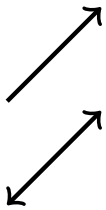


```
\draw (0,0) -- (1,1);
\draw (0,1) -- (1,0);
\draw[blue] (0,0.5) -- %
  (intersection of 0,0--1,1 and 0,1--1,0);
```

- 两条线的起点和终点不能加括号

箭头

☞ 箭头

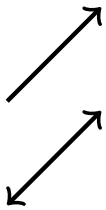


```
\draw[->] (0,0) -- (1,1);

\draw[<->] (0,0) -- (1,1);
```

箭头

☞ 箭头

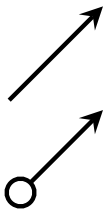


```
\draw[->] (0,0) -- (1,1);
```

```
\draw[<->] (0,0) -- (1,1);
```

➜ 使用各种类型的箭头：调用 arrows 扩展

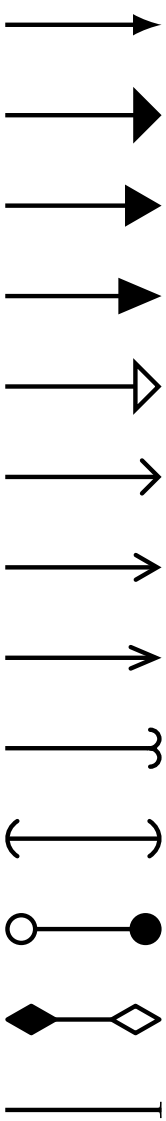
```
\usetikzlibrary{arrows}
```



```
\draw[thick,->,>=stealth] (0,0) -- (1,1);
```

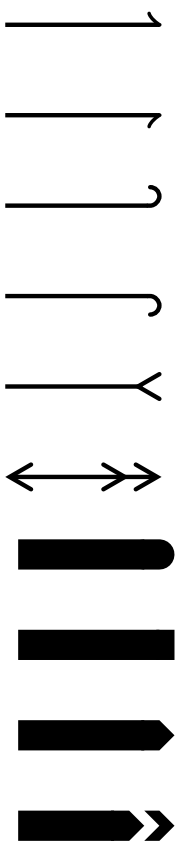
```
\draw[o-stealth] (0,0) -- (1,1);
```

箭头



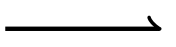
```
\draw[->,>=latex] (0,0) -- (1,0);
\draw[->,>=triangle 90] (0,0) -- (1,0);
\draw[->,>=triangle 60] (0,0) -- (1,0);
\draw[->,>=triangle 45] (0,0) -- (1,0);
\draw[->,>=open triangle 90] (0,0)--(1,0);
\draw[->,>=angle 90] (0,0) -- (1,0);
\draw[->,>=angle 60] (0,0) -- (1,0);
\draw[->,>=angle 45] (0,0) -- (1,0);
\draw[->,>=hooks] (0,0) -- (1,0);
\draw[(-)] (0,0) -- (1,0);
\draw[o-*] (0,0) -- (1,0);
\draw[diamond-open diamond] (0,0)--(1,0);
\draw[->,>=serif cm] (0,0) -- (1,0);
```

箭头

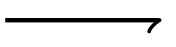


```
\draw[->,>=left to] (0,0) -- (1,0);
\draw[->,>=right to] (0,0) -- (1,0);
\draw[->,>=left hook] (0,0) -- (1,0);
\draw[->,>=right hook] (0,0) -- (1,0);
\draw[->,>=angle 60 reversed] (0,0)--(1,0);
\draw[<->>,>=angle 60] (0,0)--(1,0);
\draw[->,>=round cap] (0,0) -- (1,0);
\draw[->,>=butt cap] (0,0) -- (1,0);
\draw[->,>=triangle 90 cap] (0,0)--(1,0);
\draw[->,>=fast cap] (0,0) -- (1,0);
```

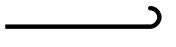
箭头



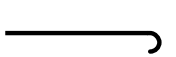
```
\draw[->,>=left to] (0,0) -- (1,0);
```



```
\draw[->,>=right to] (0,0) -- (1,0);
```

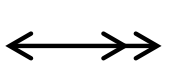


```
\draw[->,>=left hook] (0,0) -- (1,0);
```



```
\draw[->,>=right hook] (0,0) -- (1,0);
```

```
\draw[->,>=angle 60 reversed] (0,0)--(1,0);
```



```
\draw[<->>,>=angle 60] (0,0)--(1,0);
```

```
\draw[->,>=round cap] (0,0) -- (1,0);
```

```
\draw[->,>=butt cap] (0,0) -- (1,0);
```

```
\draw[->,>=triangle 90 cap] (0,0)--(1,0);
```

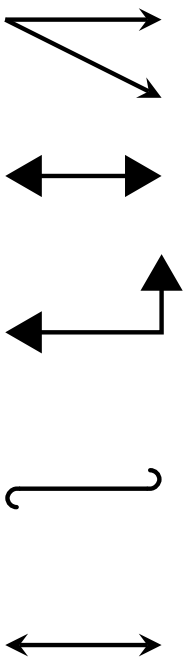


```
\draw[->,>=fast cap] (0,0) -- (1,0);
```

- reversed 参数几乎对所以箭头都适用
- 折线、弧线也可以加箭头
- 最后四个命令中加了参数： line width=1ex

参数的作用域

- \begin{tikzpicture}[参数]：对整个绘图起作用
- draw[参数]：对所绘的图形起作用
- scope 环境：可用来控制局部环境中的参数作用范围

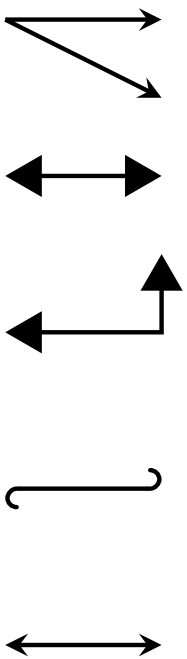


```
\begin{tikzpicture}[>=stealth]
  \draw[->] (0,4) -- (1,4);
  \draw[->] (0,4) -- (1,3.5);
  \begin{scope}[>=triangle 60]
    \draw[<->] (0,3) -- (1,3);
    \draw[<->] (0,2) -- (1,2) -- (1,2.5);
    \draw[<->,>=left hook] (0,1) -- (1,1);
  \end{scope}
  \draw[<->] (0,0) -- (1,0);
\end{tikzpicture}
```

参数的作用域

☞ 调用 scopes 扩展后，可以使用大括号替代 scope 环境

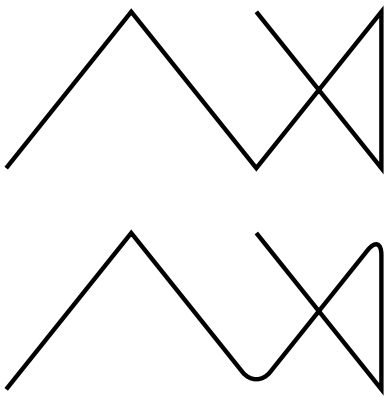
```
\usetikzlibrary{scopes}
```



```
\begin{tikzpicture}[>=stealth]
  \draw[->] (0,4) -- (1,4);
  \draw[->] (0,4) -- (1,3.5);
  { [>=triangle 60]
    \draw[<->] (0,3) -- (1,3);
    \draw[<->] (0,2) -- (1,2) -- (1,2.5);
    \draw[<->,>=left hook] (0,1) -- (1,1);
  }
  \draw[<->] (0,0) -- (1,0);
\end{tikzpicture}
```

参数的作用域

☞ 可以在一个路径内部使用 scope



```
\tikz\draw (0,0) -- (1,1) %
           -- (2,0) -- (3,1)
           -- (3,0) -- (2,1);\\[10pt]
\tikz\draw (0,0) -- (1,1) %
  { [rounded corners]--(2,0)--(3,1) }%
  -- (3,0) -- (2,1);
```

➜ 有许多选项不支持这种用法，如线的颜色等

坐标变换

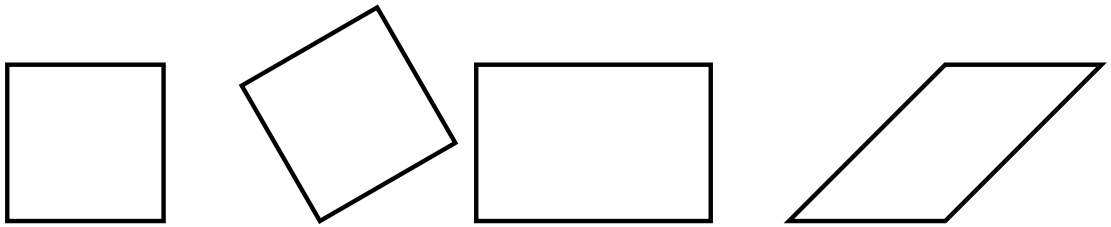
☞ xshift, yshift, shift：移动一定的距离 (要带单位)

如：xshift=2pt，shift={(2pt,3pt)}，. . .

```
\begin{tikzpicture}
  \draw (0,0) -- (1,0) %
  [yshift=3pt] (0,0) -- (1,0);
\end{tikzpicture}
```

```
\begin{tikzpicture}
  \fill[blue] (0,0) circle (2pt) %
  [shift={(5pt,5pt)}] (0,0) circle (2pt) %
  [shift={(5pt,5pt)}] (0,0) circle (2pt);
\end{tikzpicture}
```

- rotate：旋转一定角度，如：rotate=30
- scale, xscale, yscale：缩放，如：
  scale=2, xscale=-1 (翻转)
- xslant, yslant：倾斜



```
\begin{tikzpicture}
  \draw (0,0) rectangle (1,1);
  \draw[xshift=2 cm,rotate=30] (0,0) rectangle (1,1);
  \draw[xshift=3 cm,xscale=1.5] (0,0) rectangle (1,1);
  \draw[xshift=5 cm,xslant=1] (0,0) rectangle (1,1);
\end{tikzpicture}
```

重复动作

☞ 重复动作：for 循环

```
\foreach 变量 in {值表} 命令
```

➜ 命令可以使用大括号括起来，或以分号结束

$y = 1, y = 2, y = 3,$ `\foreach \x in {1,2,3} {$y=\x,$};`

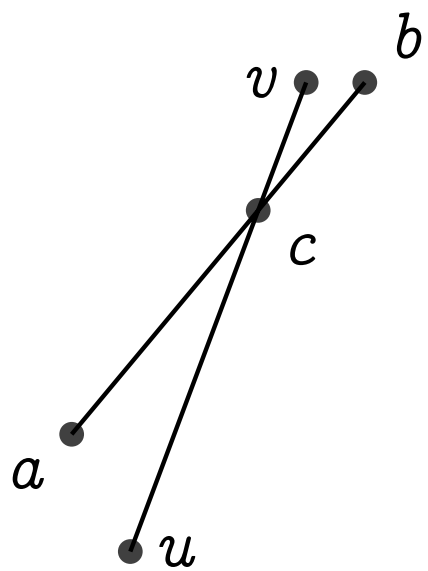
○ ○ ○ ○ ○ ○ ○ ○ ○ ○

```
\foreach \x in {1,...,10}
    \draw (\x,0) circle (3pt);
```

➜ \foreach 可是使用多个变量

添加标注

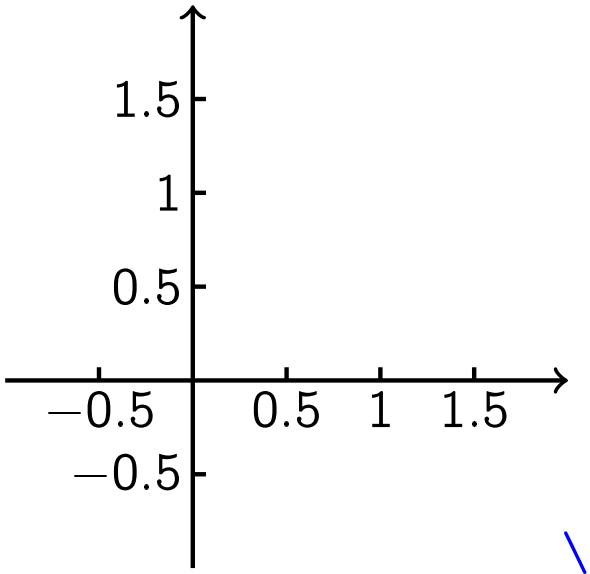
☞ \coordinate [label=角度:标注] (标记) at (x,y)




```
\begin{tikzpicture}[thick]
  \coordinate [label=-135:$a$] (a) at (0,0);
  \coordinate [label=45:$b$] (b) at (2.5,3);
  \coordinate [label=0:$u$] (u) at (0.5,-1);
  \coordinate [label=180:$v$] (v) at (2,3);
  \draw (a) -- (b)  (u) -- (v);
  \coordinate [label=-45:$c$] (c) at %
      (intersection of a--b and u--v);
  \foreach \p in {a,b,c,u,v} \fill %
     [opacity=0.75] (\p) circle (2pt);
\end{tikzpicture}
```

添加标注

☞ 添加标注：node

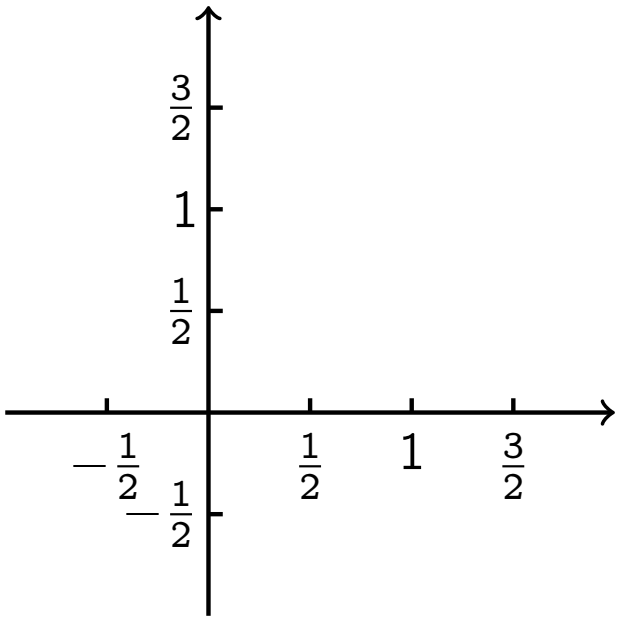



```
\begin{tikzpicture}
  \draw[->] (-1,0) -- (2,0);
  \draw[->] (0,-1) -- (0,2);
  \foreach \x in {-0.5,0.5,1,1.5}
    \draw (\x cm,0pt) -- (\x cm, 2pt)
     node[anchor=north] {\small $\x$};
  \foreach \y in {-0.5,0.5,1,1.5}
    \draw (0pt,\y cm) -- (2pt,\y cm)
     node[anchor=east] {\small $\y$};
\end{tikzpicture}
```

➜ anchor 选项：指定文本排放的相对位置，取值有：north, south, west, east 以及它们的组合

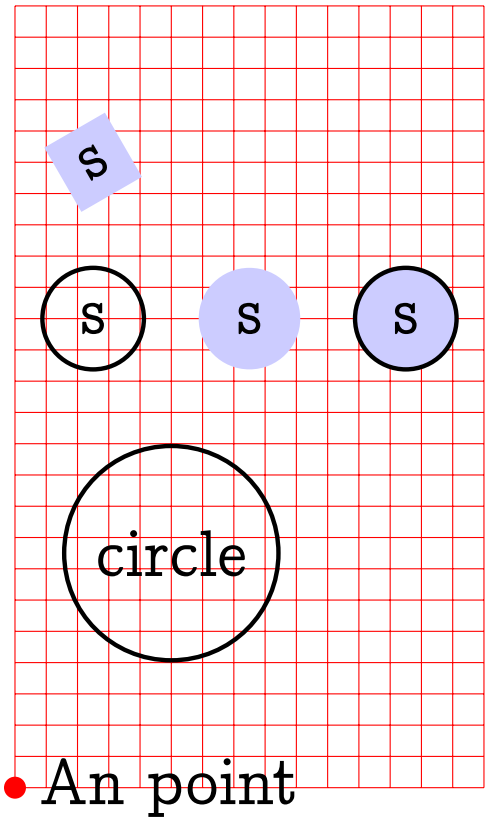
\foreach 多变量举例

➜ 也可以直接使用 below, above, left, right 等，并可以设置额外的平移距离



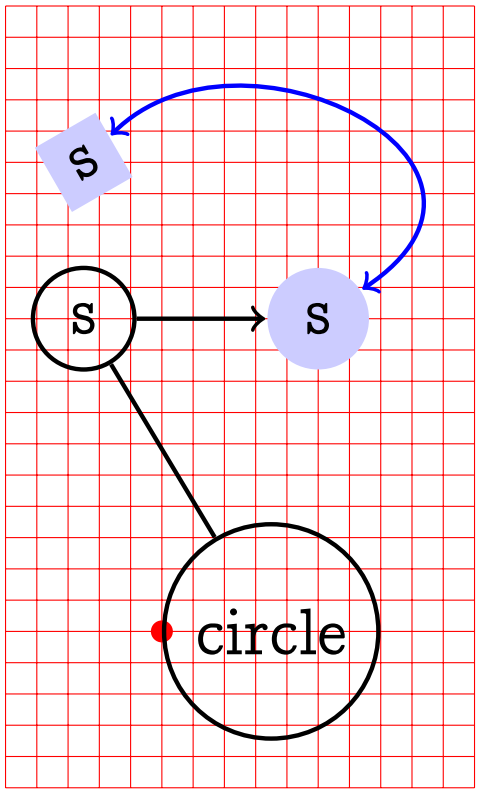

```
\begin{tikzpicture}
  \draw[->] (-1,0) -- (2,0);
  \draw[->] (0,-1) -- (0,2);
  \foreach \x/\y in %
    {-0.5/-\frac12,0.5/\frac12,1,1.5/\frac32}
    \draw (\x cm,0pt) -- (\x cm, 2pt)
     node[below=2pt] {\small $\y$};
  \foreach \x/\y in %
    {-0.5/-\frac12,0.5/\frac12,1,1.5/\frac32}
    \draw (0pt,\x cm) -- (2pt,\x cm)
     node[left] {\small $\y$};
\end{tikzpicture}
```

☞ \node[选项] at (x,y) [选项] {text}




```
\begin{tikzpicture}[thick,fill=blue!20]
  \draw[step=0.2cm,red,very thin]%
       (0,0) grid (3,5);
  \fill[red] (0,0) circle (2pt);
  \node[right=0] at (0,0) {An point};
  \node at (1,1.5) [circle,draw] {circle};
  \node at (0.5,3) [circle,draw] {s};
  \node at (1.5,3) [circle,fill] {s};
  \node at (2.5,3) [circle,draw,fill] {s};
  \node at (0.5,4) [fill,rotate=30] {s};
\end{tikzpicture}
```

☞ \node(标记)[选项] at (x,y) [选项] {text}




```
\begin{tikzpicture}[thick,fill=blue!20]
  \draw[step=0.2cm,red,very thin]%
       (0,0) grid (3,5);
  \fill[red] (1,1) circle (2pt);
  \node(a)[right=0] at (1,1) %
          [circle,draw] {circle};
  \node(b) at (0.5,3) [circle,draw] {s};
  \node(c) at (2,3) [circle,draw,fill] {s};
  \node(d) at (0.5,4) [fill,rotate=30] {s};
  \draw (a) -- (b) [->]-- (c);
  \draw[blue,<->] (d) .. controls +(1,1) %
       and +(1.5,1) .. (c);
\end{tikzpicture}
```